Variation in Cadmium Bioavailability within the Buffalo National River Watershed

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Introduction: Trace Metals in the Environment

- Toxic pollutants and essential micronutrients
  - Nonessential: Cadmium, Arsenic, Mercury, and Lead
  - Essential: Copper, Zinc, and Iron

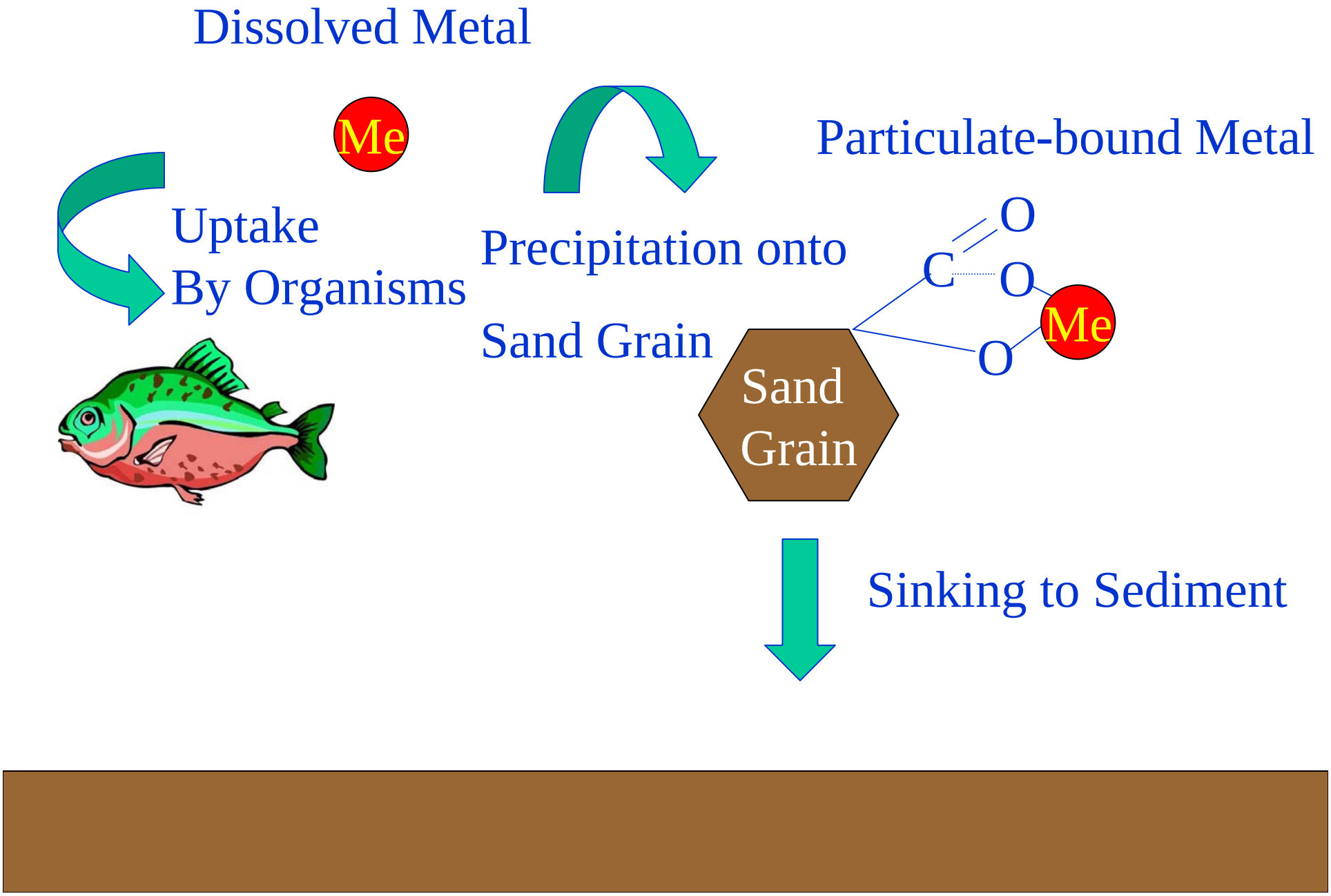
- Sources of metals in aquatic ecosystems
  - atmospheric deposition (fossil fuel combustion)
  - surface runoff (mining activities)
  - sewage and industrial outfalls

- Bioaccumulate and possibly biomagnify in food chain causing ecological and human health concerns

Uptake of Metals: Geochemistry

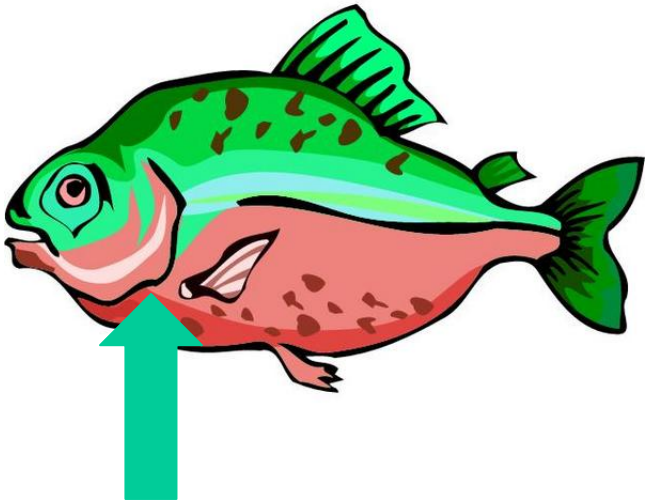
- Chemical form can influence uptake by aquatic organisms
  - Dissolved (more toxic)
  - Particulate (bound to sediment or organic material, less toxic)

- Environmental Factors influence the chemical form e.g. temperature, pH, hardness, salinity, etc.
  - Low pH: metals are in the dissolved form (toxic)
  - High pH: metals are bound to particulates (less toxic)


Dissolved Metal
Me
Particulate-bound Metal
Uptake
By Organisms
Precipitation onto
Sand Grain
O
C
O
Me
O
Sand
Grain
Sinking to Sediment

Uptake of Metals: Biochemistry

- Metals and other elements or compounds may compete for uptake across cell membranes (gills) due to chemical similarity
  - Calcium (Ca) may inhibit the uptake of Cadmium (Cd)
  - Phosphate may displace the uptake of Arsenic



Ca^{2+}

X

Cd^{2+}

Ca blocks the uptake of Cd across the gills

Cadmium

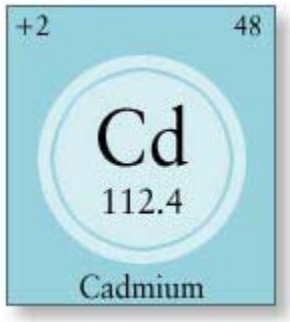
Found naturally in earth's crust in association with zinc, lead, and copper ores.

Concentrations tend to be low in surface water

Mining, smelting, and refining of ores increases Cd in the environment

Highly toxic at low concentrations (nonessential) and accumulates in biota

Low concentrations may cause growth, behavioral and physiological problems in fish



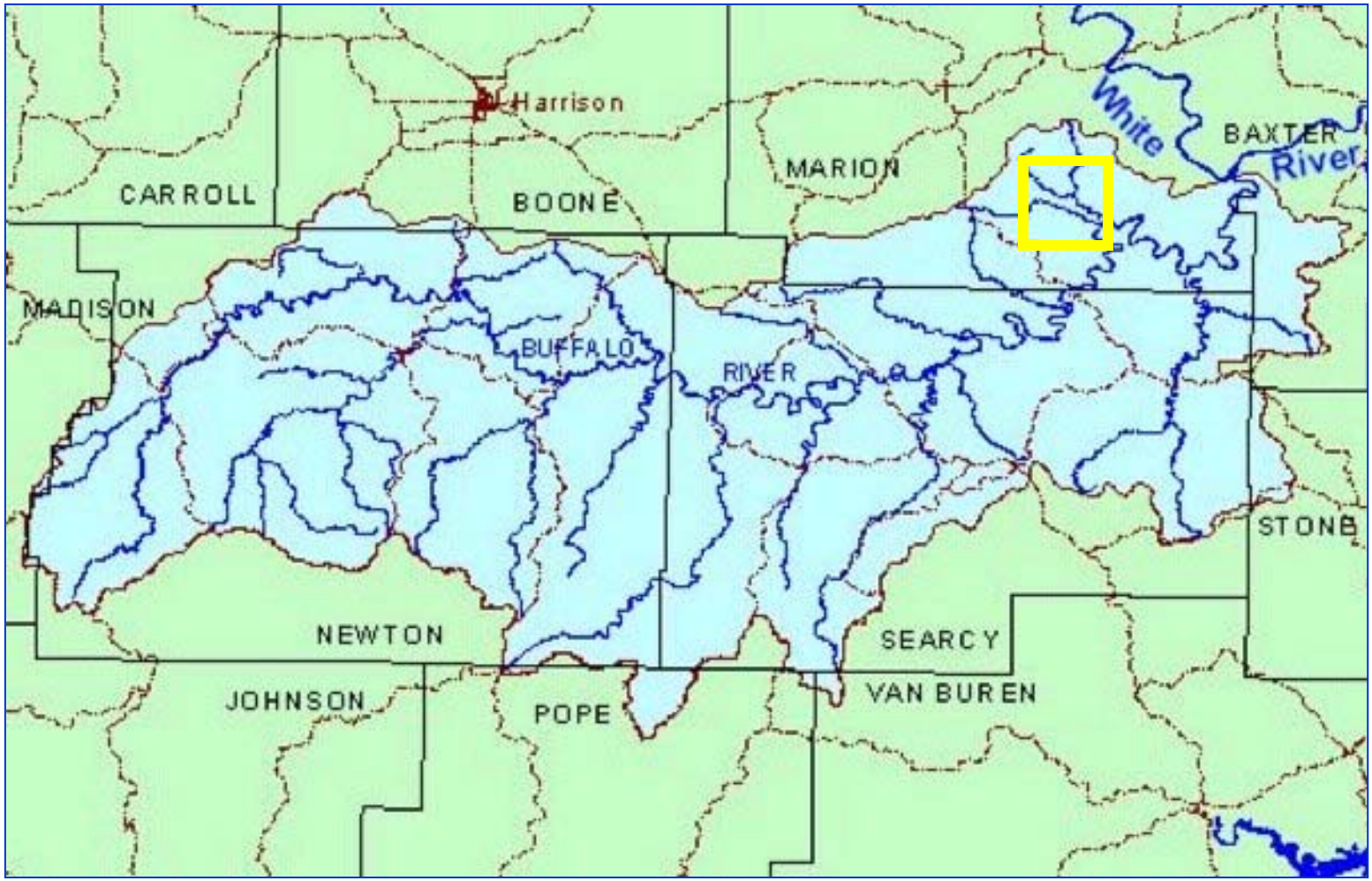
Field Study Objectives

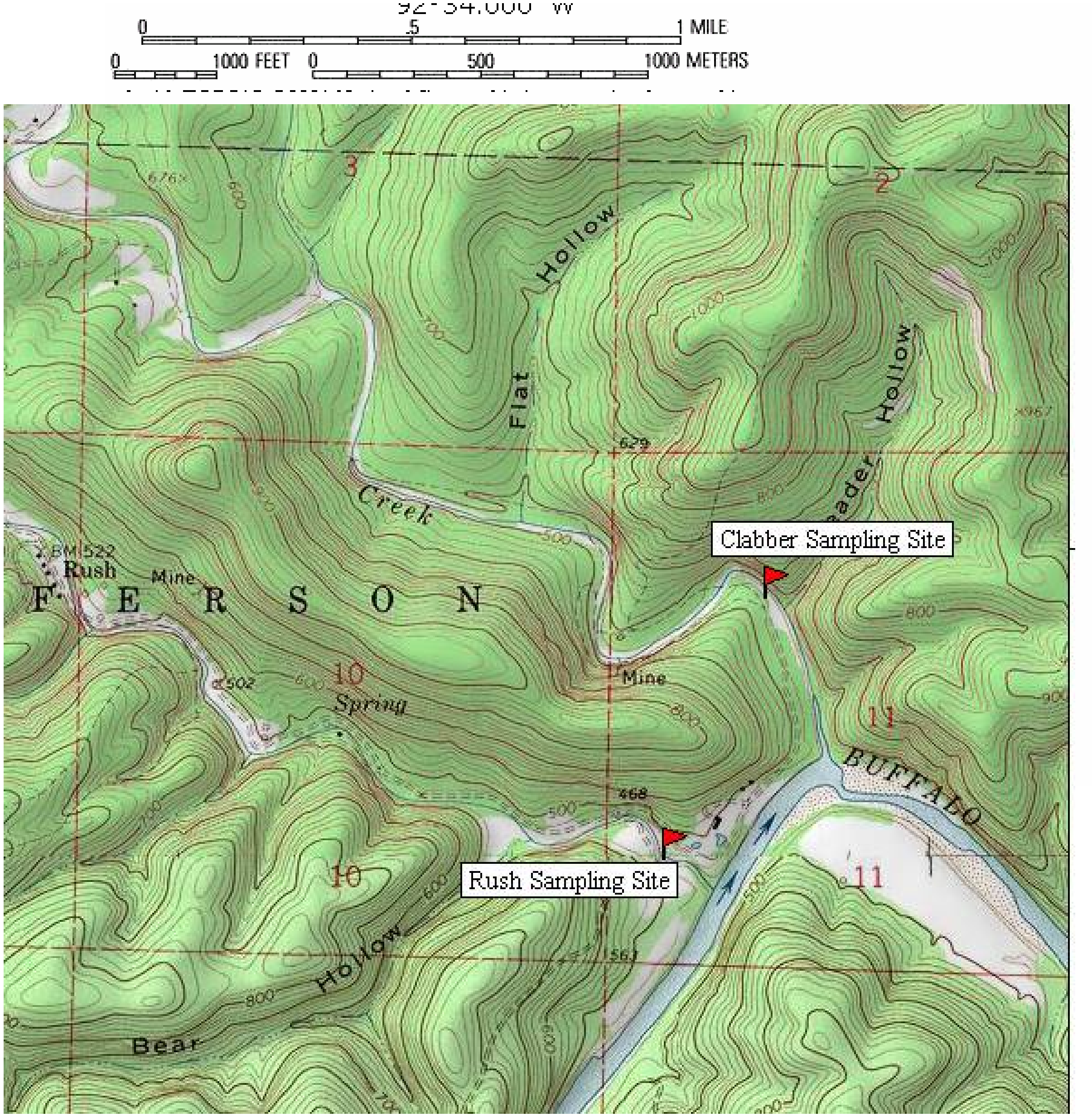
- Determine which environmental variables are the best predictors of Cd uptake by aquatic organisms
- Determine if land use patterns can be used to predict adverse effects from Cd pollution

Field Study Design

- Study was conducted on two creeks in the Buffalo National River watershed in an area of historic Pb-Zn mining activity
- Streams have different hydrologic characteristics:
  - Rush Creek: intermittent, silt-sand substrate, low flow volume, low nutrients
  - Clabber Creek: continuous flow, high flow volume, hard bottom limestone substrate, high nutrients


White/Buffalo River Basin


Harrison
CARROLL
BOONE
MARION
White
River
BAXTER
MADISON
BUFFALO
RIVER
STONE
NEWTON
SEARCY
JOHNSON
POPE
VAN BUREN



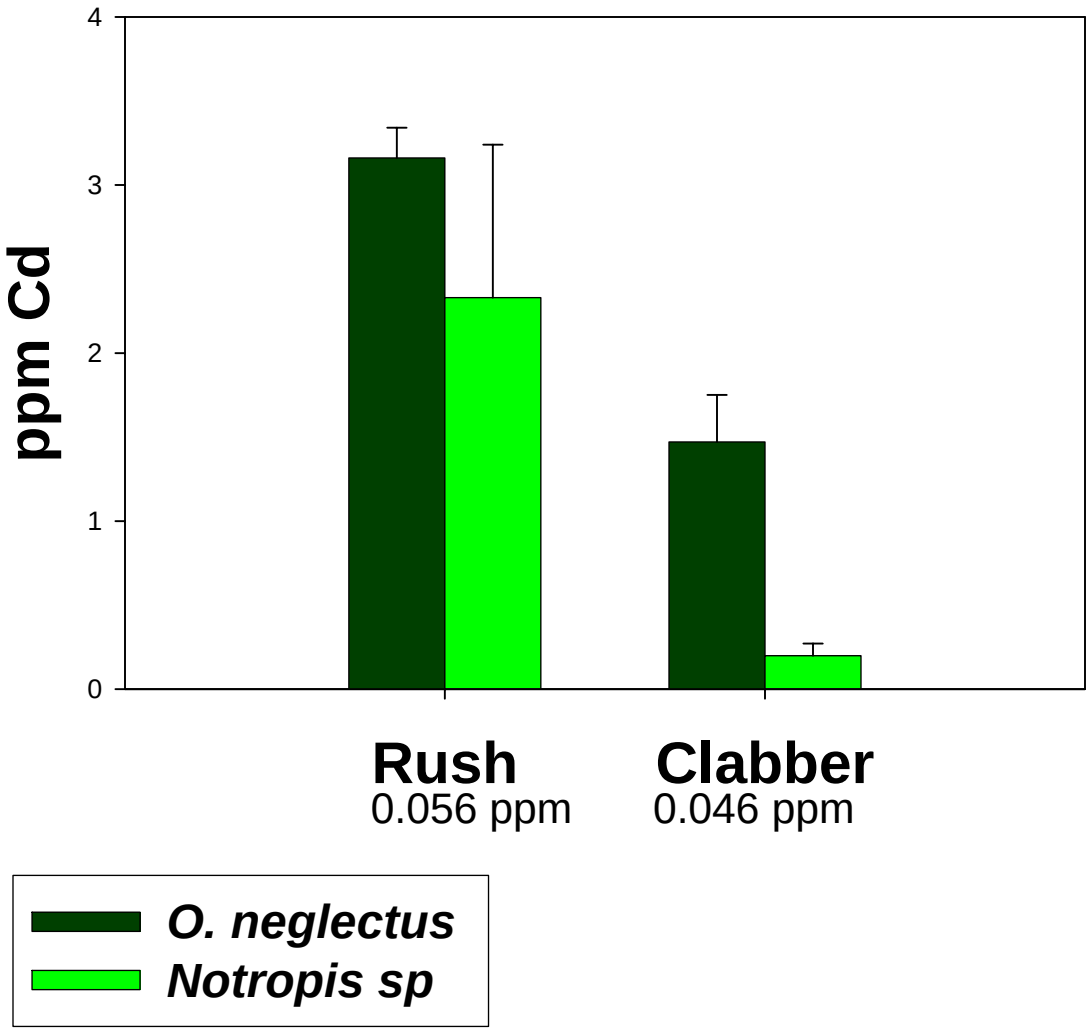
0
.5
1 MILE
0
1000 FEET
0
500
1000 METERS
Clabber Sampling Site
Rush Sampling Site
Flat
Hollow
Hollow
Creek
Rush
Mine
Mine
F E R S O N
Spring
BUFFALO
Bear
Hollow

Study Design

- Water (dissolved and particulate) and sediment were analyzed for metals
- Organisms collected and analyzed for metals
  - Crayfish (*Orconectes neglectus*)
  - Minnows (*Notropis* sp)
- Environmental parameters also measured

  I.e. dissolved oxygen, pH, phosphate, nitrate, conductivity, hardness, etc.

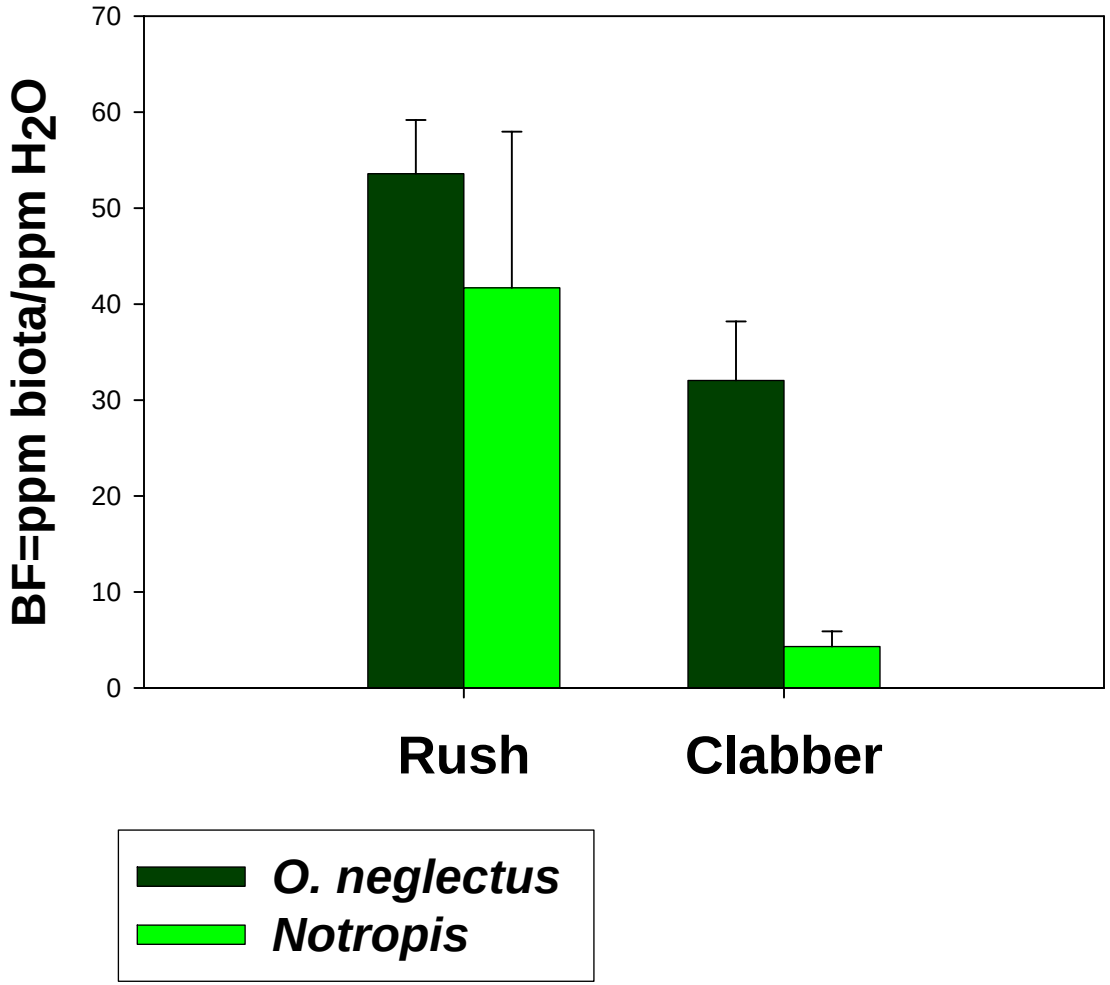
Cd Body Burdens from Rush and Clabber Creek



Bioconcentration Factor (BF):

$$\frac{\text{concentration (ppm) in organism}}{\text{concentration (ppm) in water}}$$

Cd Bioconcentration Factors of Biota from Rush and Clabber Creeks



Why are the bioconcentration factors between the two streams different?

- Biological/behavior factors e.g., Clabber Creek may have more immigration of fish species from the Buffalo River
- Water chemistry variability
  - Rush Creek: 175 ± 8 ppm $CaCO_3$
  - Clabber Creek: 230 ± 9 ppm $CaCO_3$

Laboratory Experiment Objective

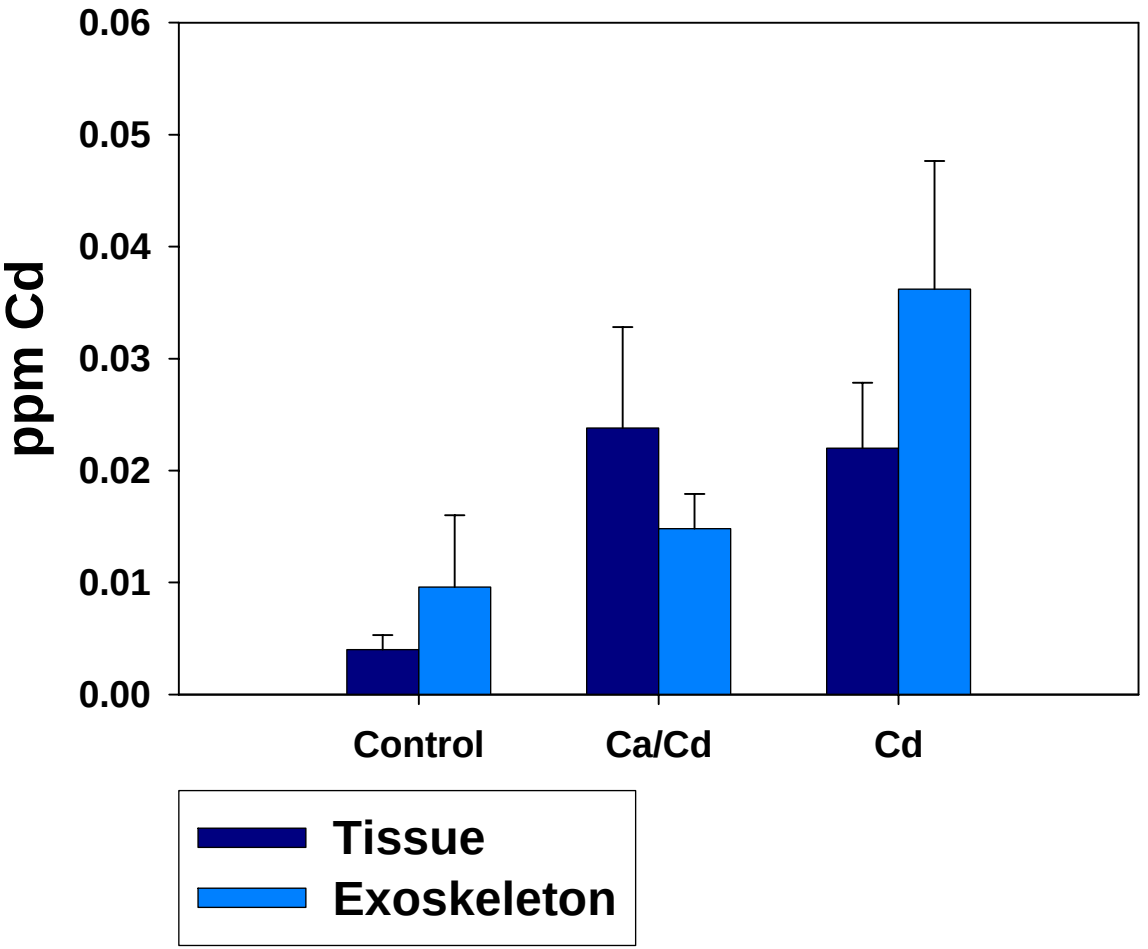
- Determine if Cd uptake by Crayfish is enhanced during Ca limitation
- Determine if Cd is sequestered in the exoskeleton

Methods

- Crayfish were exposed in individual jars containing Cd-spiked (0.05 ppm Cd) artificial pond water (APW) with or without amended Ca (20 ppm)
- Controls: APW without Cd
- 4 replicates for each treatment
- Water changed every other day
- 15 days duration
- After exposure, Cd was measured in exoskeleton and soft tissues


CONTROL
AFW

The influence of Ca^{2+} on the uptake of Cd by Crayfish



Conclusions from Ca/Cd uptake study

- Ca decreases the uptake of Cd
- May be due to competition for binding sites between the Ca/Cd
- No significant difference between soft tissue and exoskeleton, but exoskeleton tended to be higher without the presence of Ca
- Ca and other elements could be an important consideration for predicting risk from Cd pollution

Summary and Future Studies

- Water chemistry characteristics need to be taken into consideration when attempting to predict risk from metal pollution
- More field studies comparing metal tissue levels among watersheds with different water chemistries
- More laboratory experiments: metal-interactions with organic carbon, nutrients, etc.

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